Reconfigurable Sensors

For Satellites, Landers, and Rovers

Tiny Modules Needed

- Light weight
- Low power consumption
- Extreme environment (temperature, shock, radiation)
- Sometimes must sacrifice to get the above

Two Approaches

- Reconfigurable
  - Examples
    - Computers
    - Field Programmable Gate Arrays
- Specialized one-off design
  - Motivation
    - Extreme simplicity or optimized for the problem

Why Reconfigurable?

- Reuse and Economies of Scale
  - Multiple sensors with the same core physical design can perform different functions
  - Reuse “software” (both computer code and VHDL) on next generation chips
- Shorten time to launch, reduce unrecoverable design errors, reduce cost
  - Change VHDL and software, not hardware
    - Hardware design and testing cycle partially done
    - Software partially done and tested
  - Can update on orbit if necessary
- Change personality of satellites and sensors
  - Same satellite hardware can have multiple functions and support multiple missions

Why not reconfigurable?

- Reconfigurability may
  - Increase complexity
  - Reduce reliability
    - More prone to human error
    - Parts with smaller features = increased failures
      - Not all parts may be sufficiently radiation resistant
  - Increase power consumption over custom ASICs
- We don’t do it that way

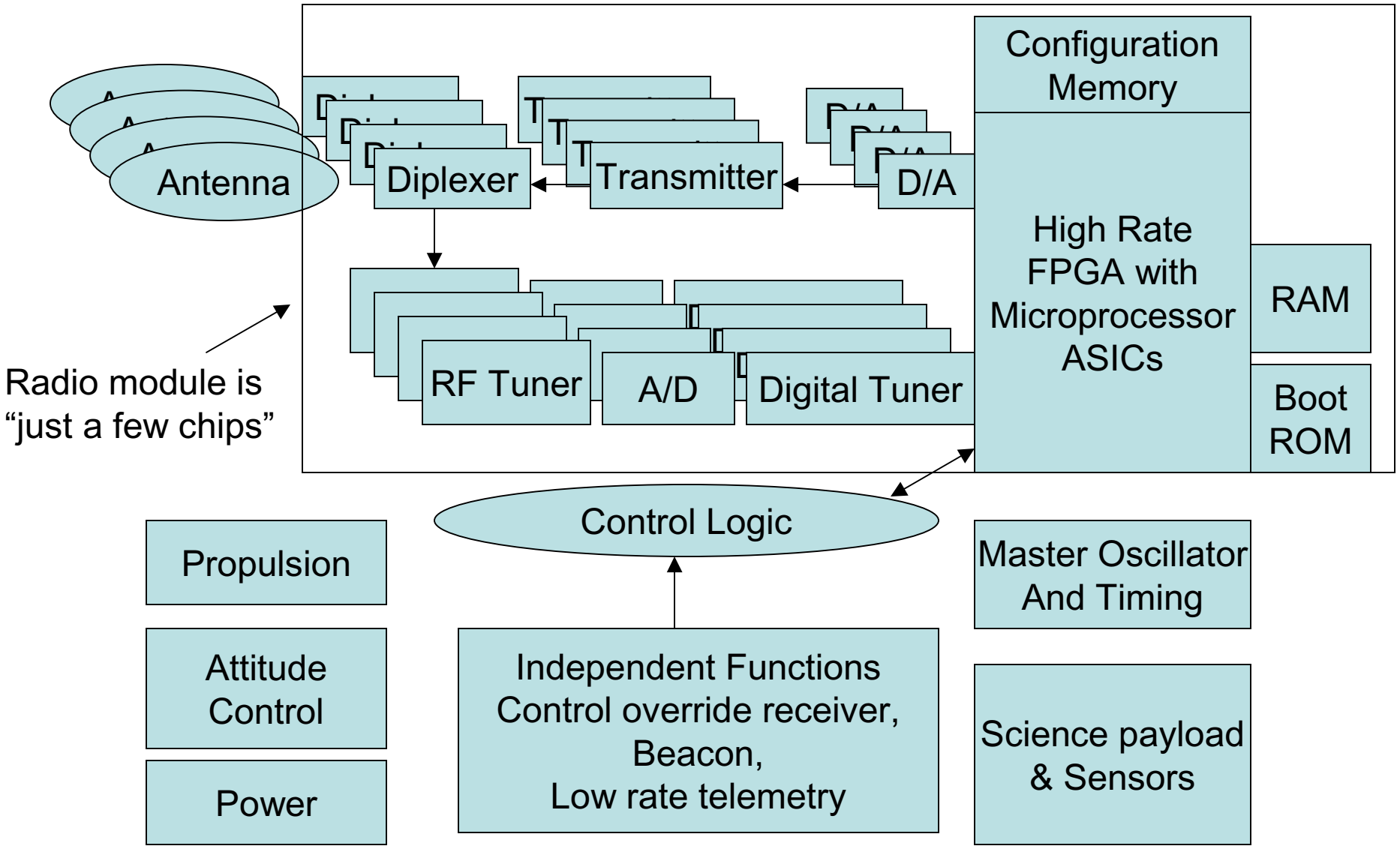
Types of Tiny Modules

- Power (solar power, storage, conversion, high peak power)
- Attitude and acceleration sensors
  - Both absolute attitude and rate
- Attitude control
- Re-entry and landing systems
- Computers
  - Control, random logic
- Reconfigurable Radios
  - Data and control, variable rates and power
  - Beacon, navigation, and radar modes
- Location and velocity sensors
- Micro-mechanical devices
  - Windshield wipers (solar array and optics cleaners)
  - Actuators to deploy or point (solar arrays, radio antennas, sensor arrays)
  - Actuators to control valves (release gas, control fluid circulation, etc.)

More Types of Tiny Modules

- Environment sensors
  - Pressure, temperature, humidity, etc.
  - Wind sensors
  - IR-UV spectrometers
  - Imaging cameras
  - Neutron detectors
  - Gamma ray detectors
  - Magnetometer
  - Seismometer
  - Acoustic sensor
  - Trace gas sensors
  - Mass spectrometers
  - Scatterometers
  - Chemical analysis
  - Dielectric constant
  - And many other scientific measurements

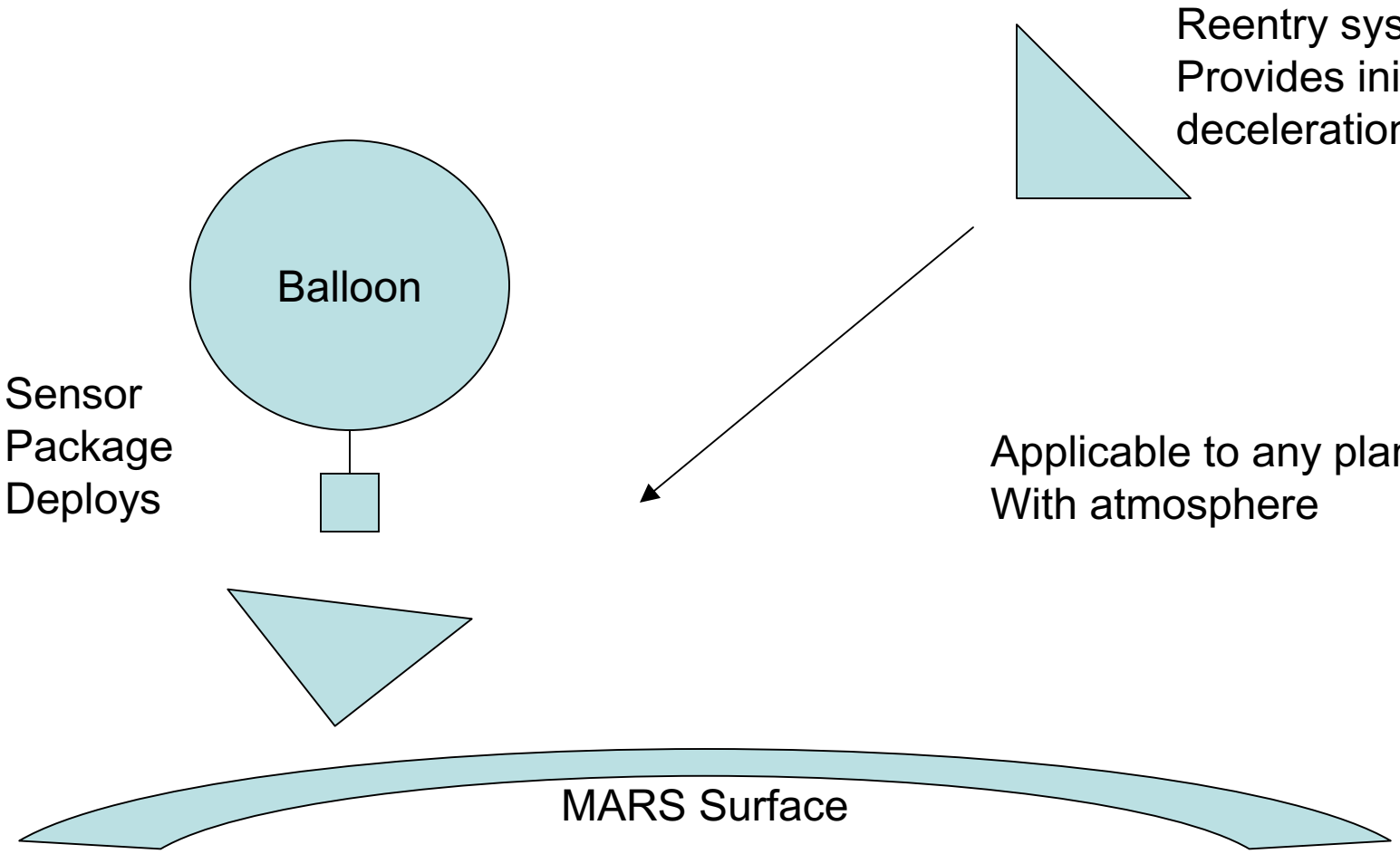
Example of Satellite Modules
As Seen by a Radio Guy



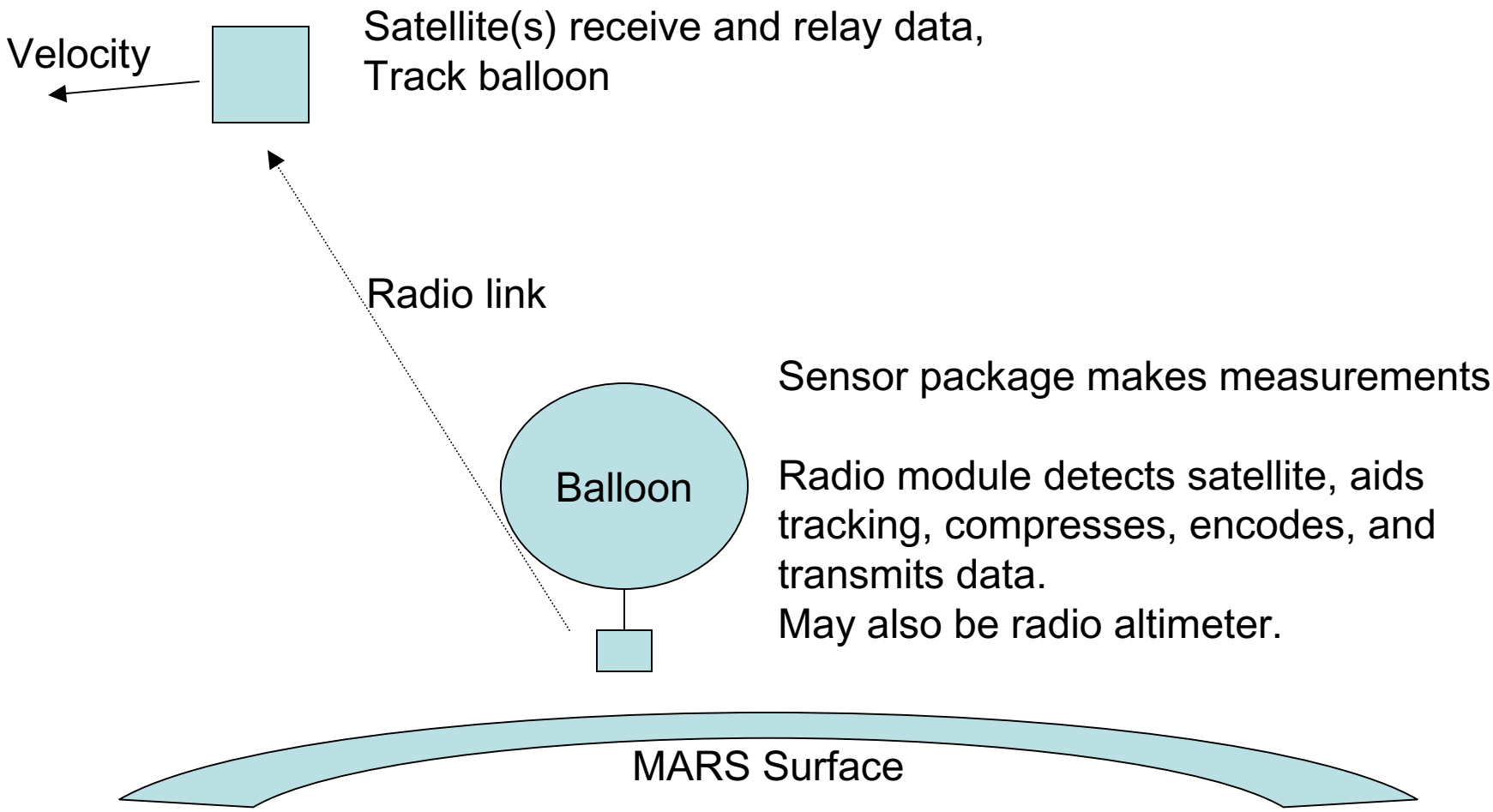
Example: Floating Atmospheric Sensor

- Deployed on Earth
  - Phase 1…balloon launched from surface with instruments recovered by glider
  - Phase 2…balloon deployed from tiny re-entry system
  - Data collection, tracking, and control initially performed from ground, eventually from satellites
- Deployed on Mars
  - Balloons deployed from tiny re-entry system
  - Data collection, tracking, and control performed from satellites in Mars orbit

Floating Sensor Package



Floater at Mars or Other world



Floater Measurement Possibilities

- Attitude sensor
  - Perhaps gravity plus sun angle
- Location sensor
  - Orbital beacon tracker
  - Terrain camera
  - Radio altimeter
- Velocity sensor
  - Multiple pictures
  - Doppler radar
- Atmospheric measurements
  - Pressure, temperature, trace gases (like humidity)
  - Turbulence and shear
    - Accelerometers and angular accelerometers
    - Gyros and rate gyros
- Surface measurements
  - Neutron, UV, IR, etc. sensors
- Other
  - Sound and infrasound.
  - Low frequency radio static

Floater Issues

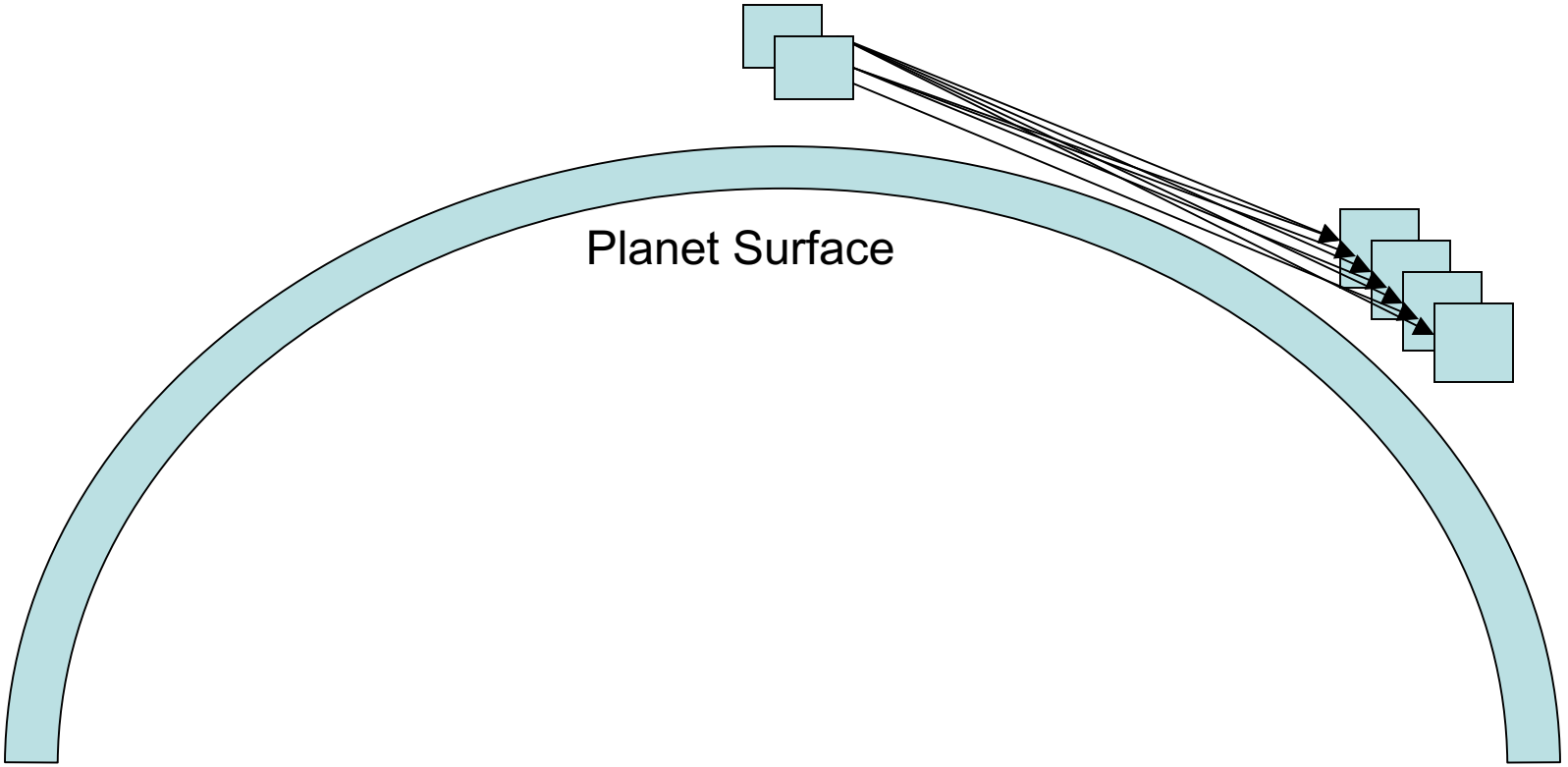
- Constraints
  - Weight of package
    - Need small for re-entry and to be lifted by balloon
  - Power consumption
    - Solar cells, weak sun, night, and dust cause problems
- Different
  - Thermal control
- Not so difficult
  - Radiation
  - Attitude control

IDEAS

- Lightning (or similar static)
  - Angle of arrival
  - Multi-satellite Time-difference of arrival
  - Trigger visual image capture
- Astronomical measurements in conjunction with ground antenna
  - Method
    - Line aperture synthesis together with TDOA of relatively strong sources
  - Objects
    - Jupiter at ~21 MHz
    - Solar flares
    - Pulsars
- Astronomical measurement with single satellite AOA
  - Transient phenomena below 1 MHz.
- Astronomical measurements with satellite constellation (possibly tethered and spinning)
  - Radio image phenomena below 10 MHz.

More Ideas

- Occultation measurements for atmospheric sensing
- Dielectric constant measurement



Even More Ideas

- Survey and locate earth-based radio pollution
  - Radio astronomy bands
  - Unlicensed bands (e.g. 2.4 and 5 GHz)
  - GPS band
- Additional element in Search and Rescue
  - 121.5, 243, and 401 MHz. perhaps with onboard processing.
- Ionospheric measurements
  - Perhaps in conjunction with Transit satellites (150 and 400 MHz) if they still exist
  - Perhaps using GPS and WAAS
  - Perhaps using ham beacons at 20 and 10 meters
  - Perhaps using loran C at 100 kHz
  - Perhaps at VLF
  - Perhaps transmitting and receiving 10 meter beacons
    - Note potential for vertical sounding with earth reflection
- Sensor package tracking, and data readout
- Demo of formation data network and tracking using commercial technology such as bluetooth, 802.11, etc.

How might RRC help

- Reconfigurable radios
  - Developing reconfigurable sensor “brick”
    - Universities might use hardware for testing and development, but not planned to be radiation hard
    - Potentially share VHDL…e.g. turbodecoder
  - Signal processing software that runs on general purpose computers
    - Have permission to release M2K® for tracking and demodulating beacon. Extremely flexible software infrastructure
- Remotely controlled ground station network
  - Possibility for dual use of equipment, software, etc.